PB-240 515

MC QUADE LAKE, ST. LOUIS COUNTY, MINNESOTA

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center
Minnesota Pollution Control Agency
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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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REPORT
ON
MCQUADE LAKE
ST. LOUIS COUNTY
MINNESOTA
EPA REGION V
WORKING PAPER NO. 112

WITH THE COOPERATION OF THE
MINNESOTA POLLUTION CONTROL AGENCY
AND THE
MINNESOTA NATIONAL GUARD
OCTOBER, 1974

II

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Minnesota Pollution Control Agency for professional involvement and to the Minnesota National Guard for conducting the tributary sampling phase of the Survey.

Grant J. Merritt, Director of the Minnesota Pollution Control Agency, John F. McGuire, Chief, and Joel G. Schilling, Biologist, of the Section of Surface and Groundwater, Division of Water Quality, provided invaluable lake documentation and counsel during the course of the Survey; and the staff of the Section of Municipal Works, Division of Water Quality, were most helpful in identifying point sources and soliciting municipal participation in the Survey.

Major General Chester J. Moeglein, the Adjutant General of Minnesota, and Project Officer Major Adrian Beltrand, who directed the volunteer efforts of the Minnesota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

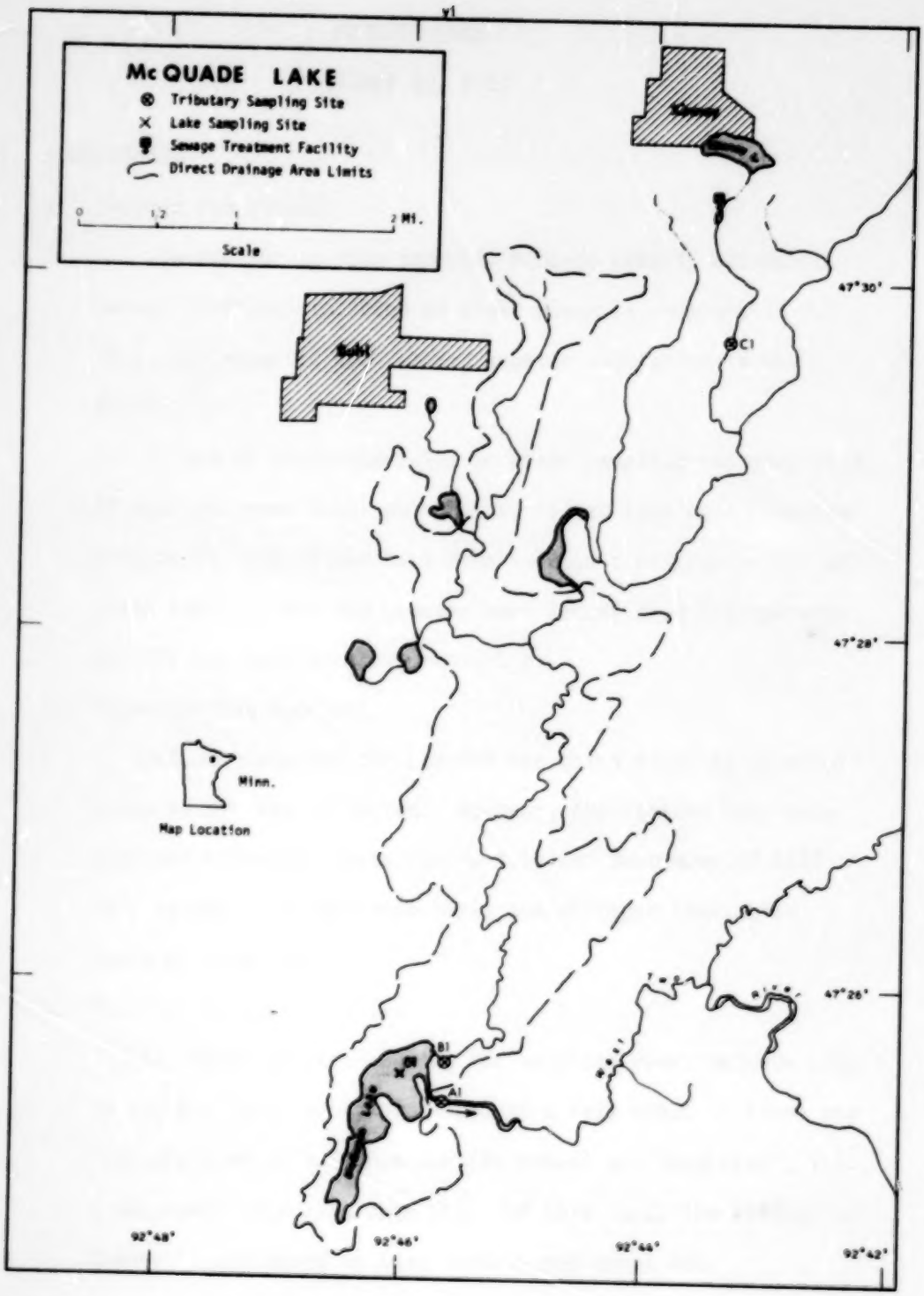
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MINNESOTA

LAKE NAME	COUNTY
Albert Lea	Freeborn
Andrusia	Beltrami
Badger	Polk
Bartlett	Koochiching
Bear	Freeborn
Bemidji	Beltrami
Big	Stearns
Big Stone	Big Stone, MN; Roberts, Grant, SD
Birch	Cass
Blackduck	Beltrami
Blackhoof	Crow Wing
Budd	Martin
Buffalo	Wright
Calhoun	Hennepin
Carlos	Douglas
Carrigan	Wright
Cass	Beltrami, Cass
Clearwater	Wright, Stearns
Cokato	Wright
Cranberry	Crow Wing
Darling	Douglas
Elbow	St. Louis
Embarass	St. Louis
Fall	Lake
Forest	Washington
Green	Kandiyohi
Gull	Cass
Heron	Jackson
Leech	Cass
Le Homme Dieu	Douglas
Lily	Blue Earth
Little	Grant
Lost	St. Louis

LAKE NAME	COUNTY
Madison	Blue Earth
Malmedal	Pope
Mashkenode	St. Louis
McQuade	St. Louis
Minnetonka	Hennepin
Minnewaska	Pope
Mud	Itasca
Nest	Kandiyohi
Pelican	St. Louis
Pepin	Goodhue, Wabasha, MN; Pierce, Pepin, WI
Rabbit	Crow Wing
Sakatah	Le Sueur
Shagawa	St. Louis
Silver	McLeod
Six Mile	St. Louis
Spring	Washington, Dakota
St. Croix	Washington, MN; St. Croix, Pierce, WI
St. Louis Bay	St. Louis, MN; Douglas, WI
Superior Bay	St. Louis, MN; Douglas, WI
Swan	Itasca
Trace	Todd
Trout	Itasca
Wagonga	Kandiyohi
Wallmark	Chisago
White Bear	Washington
Winona	Douglas
Wolf	Beltrami, Hubbard
Woodcock	Kandiyohi
Zumbro	Olmstead, Wabasha


McQUADE LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Direct Drainage Area Limits
0
1/2
1
2 MI.
Scale
Minn.
Map Location
Duluth
Superior
C1
B1
A1
47°30'
47°28'
47°26'
92°48'
92°46'
92°44'
92°42'

MCQUADE LAKE

STORET NO. 2757

I. CONCLUSIONS

A. Trophic Condition:

Limited Survey data indicate McQuade Lake is eutrophic. Survey limnologists noted an algal bloom in progress in July, 1972, and reported much rooted aquatic vegetation in the shallows.

Of the 60 Minnesota lakes on which sampling was completed, 21 had less mean total phosphorus, 15 had less mean dissolved phosphorus, and 15 had less mean inorganic nitrogen. For all lakes sampled, 46% had greater mean Secchi disc transparency, and 32% had less mean chlorophyll *a*.

B. Rate-Limiting Nutrient:

McQuade Lake was not sampled the third time, so no algal assay sample was collected. However, the limited lake data indicate nitrogen limitation in July and September of 1972 (N/P ratios were less than 10/1, and nitrogen limitation would be expected).

C. Nutrient Controllability:

1. Point sources--During the sampling year, McQuade Lake received a total phosphorus load at a rate about 1½ times the rate proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 11). Of this load, the Village of Kinney is estimated to have contributed about 46%.

It is concluded that 80% phosphorus removal at the Kinney waste treatment plant would reduce the loading rate to 6.7 lbs/acre/yr or 0.75 $g/m^2/yr$ and thus less than the eutrophic rate but greater than the oligotrophic rate.

2. Non-point sources--The estimated nutrient exports of the unnamed stream during the sampling year (see page 11) compare favorably with the exports of unimpacted Minnesota streams studied elsewhere. This indicates a lack of intensive agriculture in the area as well as a reasonable estimate of point-source loads.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS:

A. Lake Morphometry*:

1. Surface area: 164 acres.
2. Mean depth: 9 feet.
3. Maximum depth: 21 feet.
4. Volume: 1,476 acre/feet.
5. Mean hydraulic retention time: 57 days.

B. Tributary and Outlet:
(See Appendix A for flow data)

1. Tributaries -

Name	Drainage area†	Mean flow†
Unnamed Creek (B-1)	22.7 mi^2	12.1 cfs
Minor tributaries & immediate drainage -	1.8 mi^2	1.0 cfs
Totals	24.5 mi^2	13.1 cfs

2. Outlet -

West Two River	24.8 mi^{2}††	13.1 cfs††

C. Preciptation†††:

1. Year of sampling: 28.0 inches.
2. Mean annual: 26.9 inches.

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* Anonymous, 1972.

† Drainage areas are accurate within ±5%; mean daily flows are accurate within ±10%; and ungaged flows are accurate within ±10 to 25% for drainage areas greater than 10 mi^2.

†† Includes area of lake; outflow adjusted to equal sum of inflows.

††† See Working Paper No. 1, "Survey Methods".

III. LAKE WATER QUALITY SUMMARY

McQuade Lake was sampled two times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected at two depths from one station on the lake (see map, page vi). During each visit, a single depth-integrated (near bottom to surface) sample was collected for phytoplankton identification and enumeration; and a depth-integrated sample was collected for chlorophyll a analysis. The maximum depth sampled was 6 feet.

The results obtained are presented in full in Appendix B and are summarized below. The mean values presented in these summary tables are not volume-weighted; nonetheless, the means are useful as a general guide to differences in water quality at the different sampling times.

A. Physical and chemical characteristics:

Parameter	Mean Values: 1st Sample (07/08/72)	2nd Sample (09/09/72)
Temperature (Cent.)	21.6	16.3
Dissolved oxygen (mg/l)	-	9.1
Conductivity (µmhos)	130	145
pH (units)	8.4	7.9
Alkalinity (mg/l)	56	61
Total P (mg/l)	0.032	0.043
Dissolved P (mg/l)	0.012	0.021
NO_2 + NO_3 (mg/l)	0.050	0.050
Ammonia (mg/l)	0.060	0.080
Chlorophyll a (µg/l)	19.2	2.2
Secchi disc (inches)	60	48

Parameter	Min. for all samples	Max. for all samples	Mean for all samples
Temperature	16.3	21.6	19.8
Dissolved oxygen	9.1	9.1	9.1
Conductivity	130	145	140
pH	7.9	8.4	8.1
Alkalinity	56	61	59
Total P	0.032	0.046	0.039
Dissolved P	0.012	0.023	0.018
NO_2 + NO_3	0.050	0.050	0.050
Ammonia	0.060	0.080	0.073
Chlorophyll a	2.2	19.2	10.7
Secchi disc	48	60	54

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
07/08/72	1. Dinobryon	2,754
	2. Anabaena	1,920
	3. Microcystis	1,087
	4. Cryptomonas	435
	5. Tabellaria	326
	Other genera	869
	Total	7,391
09/09/72	1. Anabaena	442
	2. Melosira	382
	3. Tabellaria	291
	4. Cryptomonas	281
	5. Microcystis	221
	Other genera	803
	Total	2,420

2. Chlorophyll *a* -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll *a* (µg/l)
07/08/72	01	19.2
09/09/72	01	2.2

C. Limiting Nutrient Study:

No algal assay sample was collected, since the lake was only sampled two times.

The lake data indicate nitrogen limitation in July (N/P ratio = 9/1) and September (N/P = 6/1).

IV. NUTRIENT LOADINGS
(See Appendix C for data)

For the determination of nutrient loadings, the Minnesota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff months of April and May when two samples were collected, and the colder months when ice cover and access prevented sampling. Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Minnesota District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computor program for calculating stream loadings. Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were determined by using the pounds per square mile per year calculated for station B-1 (minus point-source loads) and multiplying that by the ZZ area in square miles.

The Village of Kinney declined participation in the Survey, and nutrient loads were estimated at 2.5 lbs P and 7.5 lbs N/capita/year.

In the tables that follow, loads attributed to tributaries are those measured minus point-source loads, if any.

A. Waste Sources:

1. Known municipal -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Kinney	325*	Imhoff tank	0.032**	Unnamed Creek

2. Known industrial - None

* Anonymous, 1973.
** Estimated at 100 gal/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Unnamed Creek (B-1)	840	48.0
b. Minor tributaries & immediate drainage (non-point load) -	70	4.0
c. Known municipal -		
Kinney	810	46.3
d. Septic tanks - None	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	30	1.7
Total	1,750	100.0

2. Outputs -

Lake outlet - West Two River 1,240

3. Net annual P accumulation - 510 pounds

* See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/yr	% of total
a. Tributaries (non-point load) -		
Unnamed Creek (B-1)	45,720	85.7
b. Minor tributaries & immediate drainage (non-point load) -	3,630	6.8
c. Known municipal -		
Kinney	2,440	4.6
d. Septic tanks - None	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	1,560	2.9
Total	53,350	100.0

2. Outputs -

Lake outlet - West Two River 46,760

3. Net annual N accumulation - 6,590 pounds

* See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr
Unnamed Creek	37	2,014

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Units	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
lbs/acre/yr	10.7	3.1	325.3	40.2
grams/m^2/yr	1.20	0.35	36.5	4.5

Vollenweider loading rates for phosphorus (g/m^2/yr) based on mean depth and mean hydraulic retention time of McQuade Lake:

"Dangerous" (eutrophic rate)	0.82
"Permissible" (oligotrophic rate)	0.41

V. LITERATURE REVIEWED

Anonymous, 1972. Survey questionnaire. MPCA, Minneapolis.

Anonymous, 1973. Wastewater disposal facilities inventory--State of Minnesota. MPCA, Minneapolis.

Vollenweider, Richard A., (in press). Input-output models. Schweiz. A. Hydrol.

VII. APPENDICES

APPENDIX A

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2757 MOOSE LAKE

TOTAL DRAINAGE AREA OF LAKE = 24.40

TRIBUTARY	SUBDRAINAGE AREA	JAN	FEB	MAR	APR	MAY	GENERALIZED FLOWS JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
275781	24.40	0.00	0.00	0.00	65.38	13.00	10.40	13.10	4.11	4.56	9.24	6.16	1.53	13.25
275791	23.30	0.00	0.00	0.00	59.60	10.20	15.30	12.00	3.75	4.20	8.39	5.60	1.45	12.12
275777	9.74	0.00	0.00	0.00	0.00	2.58	1.44	1.05	0.29	0.42	0.84	0.40	0.10	0.99

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 24.40
SUM OF SUBDRAINAGE AREAS = 24.75

TOTAL FLOW IN = 157.43
TOTAL FLOW OUT = 159.13

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
275781	10	73	5.76	15	5.70				
	11	73	3.39	15	3.40				
	12	73	1.93	18	1.80				
	1	74	0.72	14	0.40				
	2	74	1.07	4	1.20				
	3	74	0.91	10	1.30				
	4	74	14.40	5	7.40	24	28.00		
	5	74	26.10	6	22.00	21	9.00		
	6	74	12.30	14	14.00				
	9	74	5.76	17	3.50				
	10	74	7.93	21	12.10				
	11	74	2.63	14	2.20				
275791	11	73	5.63	15	5.20				
	12	73	2.45	15	3.60				
	1	74	0.55	14	0.40				
	2	74	0.74	14	0.79				
	3	74	1.13	4	1.20				
	4	74	0.84	10	1.40				
	5	74	13.11	6	7.23	24	24.00		
	6	74	23.13	6	20.00	21	8.10		
	9	74	11.30	14	13.00				
	10	74	5.28	17	3.20				
	11	74	7.20	22	9.60				
	3	74	2.64	14	2.09				
275777	10	73	0.93	15	0.45				
	11	73	0.70	15	0.20				
	12	73	0.16	15	0.05				
	1	74	0.16	14	0.04				
	2	74	0.19	4	0.05				
	3	74	0.33	10	0.07				
	4	74	1.11	6	0.40	24	2.00		
	5	74	1.05	6	1.70	21	0.70		
	6	74	1.17	14	1.24				
	9	74	0.05	17	0.24				
	10	74	1.05	21	0.40	27	0.36		
	4	74	0.75	14	0.20				

14

APPENDIX B

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 74/10/30

275701
47 25 32.0 092 45 59.0
MCQUADE LAKE
27 MINNESOTA

11FPALES 2111202
3 0006 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/08	13 30	0000	21.4		60							
	13 30	0006	21.4			130	8.40	56	0.050	0.060	0.032	0.012
72/09/09	13 00	0000			48	145	7.90	61	0.050	0.080	0.040	0.023
	13 00	0006	16.1	9.1		145	7.90	60	0.050	0.080	0.046	0.020

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/08	13 30	0000	19.2J
72/09/09	13 00	0000	3.2J

J VALUE KNOWN TO BE IN ERROR

APPENDIX C

TRIBUTARY DATA

STORET RETRIEVAL DATE 74/10/30

275/A1 LS2757A1
47 25 30.0 092 45 30.0
UNNAMED TRIB FROM LK TO W TWO RV
27 7.5 BOHL
07/COUJDE LAKE
CO HWY 453 ABOG E OF LAKE OUTLET
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/15	09 30		0.018	0.810	0.070	0.005K	0.042
72/11/15	13 10		0.072	0.720	0.100	0.008	0.038
73/04/06	09 45		0.052	3.780	0.659	0.020	0.055
73/04/24	08 45		0.010K	2.100	0.050	0.007	0.068
73/05/06	19 05		0.012	1.760	0.050	0.016	0.045
73/05/21	18 45		0.010K	1.050	0.031	0.012	0.040
73/06/18	09 35		0.010K	1.020	0.039	0.010	0.035
73/07/17	19 40		0.027	2.000	0.098	0.008	0.052
73/08/21	19 40		0.066	3.570	0.220	0.008	0.047
73/09/14	19 40		0.045	1.900	0.380	0.019	0.070

K VALUE KNOWN TO BE LESS THAN INDICATED

STORET RETRIEVAL DATE 74/10/30

275781 L5275781
47 25 30.0 092 45 30.0
UNNAMED TRIB TO NE CR MCQUADE LK
27 7.5 BUHL
1/MCQUADE LAKE
CO HWY 453 BRDG JUST E OF NE CORNER LAKE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/15	09	15	1.024	0.600	0.080	0.009	0.050
73/04/06	09	40	1.120	2.900	0.163	0.020	0.065
73/04/24	08	35	0.110	2.600	0.058	0.012	0.070
73/05/06	19	00	0.025	0.780	0.028	0.022	0.040
73/05/21	18	40	0.010K	0.760	0.048	0.021	0.060
73/06/19	09	30	0.054	1.260	0.046	0.058	0.135
73/07/17	19	35	0.017	1.760	0.054	0.032	0.070
73/08/27	19	25	0.034	2.900	0.105	0.052	0.090
73/09/14	19	35	0.150	5.200	0.210	1.052	0.105

K VALUE KNOWN TO BE LESS THAN INDICATED

STORET RETRIEVAL DATE 74/10/10

21?/C1 LS2757C1
47 29 30.0 092 43 30.0
UNNAMED OUTLET KINNEY LAKE
27 7.5 KIRK
T/MCQUADE LAKE
US 169 KING 2.25 MI BELOW KINNEY STP
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/15	09 55		0.510	0.500	0.063	0.154	0.190
72/11/16	13 30		0.640	1.200	0.580	0.294	0.336
73/04/05	10 00		0.270	6.900	0.292	0.102	0.185
73/04/24	09 05		0.140	2.730	0.100	0.025	0.060
73/05/06	19 25		0.210	0.720	0.110	0.083	0.135
73/05/21	19 00		0.085	0.650	0.050	0.084	0.140
73/06/18	09 50		0.149	1.700	0.100	0.150	0.250
73/07/17	20 00		0.350	1.470	0.054	0.220	0.260
73/08/27	20 00		0.240	2.940	0.100	0.160	0.240
73/09/14	20 00		0.660	5.700	0.360	0.270	0.330

20